10/561894

Attorney Docket No. 9A-97 303 (WUE-00001)

IAP20 Rec'd PCT/PTO 22 DEC 2005

Travelling Field Machine

Description

Field of the Invention

[0001] The present invention relates to a travelling field machine. In particular, the invention relates to a travelling field machine with a stator and a rotor, each of which comprising at least one stator coil or one rotor coil, respectively, with the stator or the rotor, respectively, comprising a soft magnetic iron body with a stator or rotor back, respectively, at which spaced grooves are formed under the forming of teeth.

Definition of Terms

[0002] The term "travelling field machines", i. e. asynchronous, synchronous, reluctance machines, permanently excited electrical machines, etc. covers motors as well as generators, whereby it is of no significance in particular for the invention whether such a machine is designed as a rotating machine or, for example, as a linear motor. Moreover, the invention may be applied both to internal rotor machines and external rotor machines.

Background of the Invention

[0003] In the reduction of the volume of highly efficient electrical machines the form of construction and the arrangement of the conductors of the field windings play a decisive role. Conductors with a minimum length in the winding overhangs at a high utilisation of the space reduce the ohmic losses and increase the

power density.

[0004] Due to the fact that the ohmic losses in the control circuit and in the (stator) winding are proportional to the current to be connected, a certain conductor length has to be provided in the magnetic field in order to generate an induced back voltage corresponding to the desired high control voltage in a conductor arrangement of a resistance as low as possible.

[0005] Conventional electrical machines in their majority are wound with continuous wires - mostly with round cross-section. Though a thin flexible wire may easily be placed into the grooves, it has the disadvantage of a poor space utilisation in the grooves and winding overhangs. Wires with round cross-section cannot fully utilise the cross-sectional area of the groove. The space in the winding overhangs is thus also utilised only inadequately, and the magnetically ineffective conductor length, the overall weight, the required space, and the ohmic losses increase.

State of the Art

[0006] From EP 1 039 616 A2 (Honda Giken) a travelling field machine is known whose stator carries a stator coil. The stator has a soft magnetic iron body with a stator back in which spaced *grooves* are formed, generating teeth. Each stator coil has a conductor bar each arranged in one of the grooves and end connectors arranged at the faces of the stator, which connect the conductor bars. All of the conductor bars *have* the same axial length. The end connectors of the stator coils are arranged in one layer at the faces of the stator transversely to the groove bottom. The end connectors are designed as symmetrical parts and project *above* the groove bottom alternately towards

the stator back and the air gap of the travelling field machine. The end connectors and the conductor bars are riveted together.

[0007] From JP 2001 275288 (Matsushita Electric Ind. Co., Ltd.) a travelling field machine is known whose stator comprises a stator back in which spaced *grooves* are formed. Conductor bars are arranged in the *grooves* of the stator back, and the projecting portions of the conductor bars are connected with stacked end connectors. Each phase has a different conductor bar length which corresponds to a certain end winding and certain conductor portions in the *grooves.* Consequently, the conductor bars in one *groove have* the same length, and each end winding plate comprises lines which connect the conductor portions of this phase. These lines *have* to be routed around the other neighbouring conductor bars.

Problem on which the Invention is Based

[0008] The *above* explained known arrangements suffer from the drawback that they meet the requirements with respect to power density and reliability only partially, as are specified for some applications.

[0009] The design of the overhangs is a decisive factor for the efficiency of the electrical machine, with the known configurations being not optimised for highly efficient machines with respect to the requirements imposed by large-scale production. Moreover, the design as described e. g. in EP 1 039 616 A2 does not allow the use of multi-layer windings, because this would result in a collision of the end connectors.

Inventive Solution

[0010] For the solution of these problems the invention teaches a travelling field machine of the *above* mentioned type with a stator and a rotor which are separated by an air gap and each of which comprises at least one stator coil or one rotor coil, respectively, with the stator or the rotor, respectively, comprising a soft magnetic iron body with a stator or rotor back, respectively, in which spaced grooves are formed, generating teeth, and in each of the grooves several conductor bars of the stator coil or the rotor coil, respectively, are arranged in series comprising end connectors arranged at the faces of the stator or the rotor, respectively, which connect the conductor bars extending across at least one groove, wherein the conductor bars arranged in a neighbouring relationship in each of the grooves, comprising conductor portions of different length projecting beyond the faces of the stator or rotor, respectively, and the end connectors are at least partially arranged layered in tiers in the axial direction at the faces of the stator or the rotor, respectively.

[0011] This design permits a maximum utilisation of the available space (both in the axial and the radial or lateral, respectively, direction) and at the same time a power optimisation of the electrical machine with a very high reliability in operation with low manufacturing costs.

Embodiments and Developments of the Invention

[0012] Preferably, the end connectors are provided with transverse portions at their two end areas, through which they are connected with the ends of the conductor bars. The length of the transverse portions determine how far the winding

overhangs originating from the conductor bars extend across the back of the rotor or the stator.

[0013] The conductor bars may have a connecting area each at their ends, which matches with corresponding portions at the end connectors for a mechanical and electrical connection. The design of the mechanical and electrical connection may be of various kinds. The connecting areas at the ends of the conductor bars or the transverse portions of the end connectors, respectively, are formed, for example, by recesses or tapers in which or to which, respectively, the corresponding portions of the end connectors or the conductor bars, respectively, are joined and contacted by laser welding or electro-impulse welding.

[0014] The joint between the end portion of the conductor bar and the end portion of the end winding may also - irrespective of the structural design of the end portion of the conductor bar and the end portion of the end winding - comprise a layer of brazing solder, preferably silver brazing solder, tin brazing older, or the like, or the connection between the end portion of the conductor bar and the end portion of the end winding has a layer of a high temperature soft solder, preferably with a melting point of at least approx. 380°C.

[0015] The transverse portions at the two end portions of the end connectors to the respective ends of the conductor bars may have different lengths and/or may be angled under different angles.

[0016] Depending on whether the electrical machine is an internal rotor or an external rotor machine, the grooves may taper or expand towards the air gap between the stator and the rotor. This allows the conductor bars arranged in the

grooves, depending on their position in the groove, to have a width which is at least partially adapted to the groove width. This provides for the maximum utilisation of the available groove space.

[0017] A good space utilisation may also be achieved in that at least on one of the two faces of the stator the end connectors are not only arranged in the direction of the stator back, but also in the direction of the air gap between the stator and the rotor. In this case, the length of the conductor bars is increasing both from the stator back and the air gap between stator and rotor towards the centre of the winding chamber.

[0018] Preferably, the conductor bars and/or the end connectors are provided with a ceramic or enamel coating. In this case, it is advantageous to join the two parts to essentially L-shaped components, to provide them with a ceramic or enamel coating prior to joining or subsequently, to then insert them in layers (from both faces) into the grooves of the soft magnetic body, and to the connect them with the respective windings.

[0019] Further characteristics, properties, advantages, and possible modifications will become apparent for those with s kill in the art from the following description in which reference is made to the accompanying drawing.

[0020] Fig. 1 illustrates a schematic perspective exploded view of a stator for an electrical machine according to the invention.

[0021] Fig. 2 schematically illustrates the construction of a winding of an electrical machine according to Fig. 1.

[0022] Figs 3a, 3b show the end connectors of the electrical machine

according to Fig. 1 in an enlarged illustration.

Detailed Description of Preferred Embodiments

[0023] Fig. 1 is a plan view of two discontinuous portions of an unwind (development) of a stator 10 of an internal rotor machine (not shown in detail), with the invention being also applicable to an external rotor machine. In the present embodiment, the stator 10 is built from stacked sheets (not shown in detail), but could also consist of iron particles which are pressed and sintered to the respective shape.

[0024] The stator 10 with a stator back 11 has grooves 12 arranged next to one another, which form winding chambers for the respective stator coil windings 14. In the shown embodiment the winding chambers 12 have an essentially rectangular cross-section, with slots 16 in the side (not shown) facing towards the rotor. Thus, one tooth 18 each is formed between two slots 16 each.

[0025] Each stator coil 14 is formed by conductor bars 20 with an essentially rectangular cross-section, which are inserted in the winding chambers 12 and joined by end connectors 22. The end connectors 22 of all windings together form winding overhangs 24 at both faces of the stator 10. For the sake of clarity, several stator coils 14 have been omitted, and the stator 10 is shown in two discontinuous portions.

[0026] The end connectors 22 are oriented essentially in a transverse direction to the bottom 17 of the grooves 16 - relative to the longitudinal axis of the conductor bars 20 - and partially protrude the bottom 17 of the grooves 16 towards the stator back 11. The end connectors 22 have an essentially parallel orientation with

respect to the face of the stator 10 or the rotor, respectively.

[0027] The end connectors 22 are joined at one or both of their end portions with the ends 26 of the conductor bars 20 by means of transverse portions 28 which are oriented transversely to the longitudinal axis of the conductor bars 20 (see also Figs 3a and 3b). The transverse portions may either be part of the end winding 22, as shown in Fig. 1, or part of the respective conductor bar 20.

[0028] As can be seen, in particular in Figs 1 and 3, the transverse portions 28 at the two end portions of the end connectors 22, which extend to the respective ends 26 of the conductor bars 20, have different lengths in order to obtain the respective relative position of the end winding 22 in the winding overhang 24. The transverse portions 28 each have a rectangular recess 28a into which the ends 26 of the conductor bars 20 are inserted and connected electrically and mechanically, e. g. by means of laser welding.

[0029] Fig. 2 schematically shows how the conductor bars 20 are joined by the end connectors 22 with their transverse portions 28 with different lengths at one end of the conductor bars 20 to form a stator coil 14.

[0030] Fig. 3a illustrates one end winding 22 with transverse portions 28 of different lengths, which is arranged in Fig. 1 at the upper end of the conductor bars 20.

[0031] Fig. 3b illustrates one end winding 22 with transverse portions 28 of the same length, which is arranged in Fig. 1 at the lower end of the conductor bars 20.

[0032] Depending on the number of phases and the number of holes of the electrical machine, the end connectors 22 span several grooves 16. Respective conductor bars 20 which are arranged in a neighbouring relationship each in one

groove have conductor portions 20', 20" of different lengths, which protrude beyond the faces of the stator 10 or the rotor, respectively. In the embodiment shown in Fig. 1, the length of the conductor portions 20', 20" increases from the stator back 11 towards the free end of the teeth 18 (in other words, towards the air gap of the electrical machine). The end connectors 22 are arranged stacked above one another in an increasing order ladder-type from the stator back 11 towards the teeth 18 in a corresponding manner.

[0033] As can also be seen from Fig. 1, end connectors of a winding overlap end connectors of another winding in the lateral direction as well (in Fig. 1 e. g., from the left to the right). Thereby the end connectors 22 with the two shortest conductor bars 20n (Fig. 1 front) of one winding 14 form the lowermost layer which is superimposed by the end connectors of the following second-shortest conductor bars 20 of this winding 14 ladder-type (in Fig. 1 rearwards). This construction is repeated to the longest conductor bars 20 (rearmost in Fig. 1) of this winding 14. Between the end connectors 22 of one winding 14 the end connectors 22 of further windings 14 project in a laterally stepped manner between.

[0034] Thus, the invention provides a very compact and space-saving arrangement of the winding overhangs of the electrical machine thanks to its ladder-type increasing conductor bars in each groove and the ladder-type end connectors of a winding encompassing one another both in the longitudinal direction of the grooves as well as the end connectors of neighbouring windings penetrating one another in an imbricated manner in a direction transverse to the grooves.

[0035] The ratios of the individual parts and portions thereof shown in the figures and their material thicknesses are not to be construed as being limiting. Rather

may individual dimensions deviate from the illustrated ones. Moreover, it is understood that the embodiments shown in the figures have to be arranged correspondingly about an axis of rotation or to be curved for rotating machines, i.e. internal or external rotor machines.